



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification 4 : G03B 41/00, G01B 11/27</p>	<p>A1</p>	<p>(11) International Publication Number: WO 85/ 04266</p> <p>(43) International Publication Date: 26 September 1985 (26.09.85)</p>		
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(21) International Application Number: PCT/US84/01542</p> <p>(22) International Filing Date: 26 September 1984 (26.09.84)</p> <p>(31) Priority Application Number: 590,135</p> <p>(32) Priority Date: 16 March 1984 (16.03.84)</p> <p>(33) Priority Country: US</p> <p>(71) Applicant: HUGHES AIRCRAFT COMPANY [US/US]; 200 North Sepulveda Boulevard, El Segundo, CA 90245 (US).</p> <p>(72) Inventor: BARTELT, John, L. ; 1504 Folkstone Terrace, Westlake Village, CA 91361 (US).</p> <p>(74) Agents: COLLINS, David, W. et al.; Hughes Aircraft Company, P.O. Box 1042, Bldg. C-2, MS A-126, El Segundo, CA 90245 (US).</p> </td> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent).</p> <p>Published <i>With international search report.</i></p> </td> </tr> </table>			<p>(21) International Application Number: PCT/US84/01542</p> <p>(22) International Filing Date: 26 September 1984 (26.09.84)</p> <p>(31) Priority Application Number: 590,135</p> <p>(32) Priority Date: 16 March 1984 (16.03.84)</p> <p>(33) Priority Country: US</p> <p>(71) Applicant: HUGHES AIRCRAFT COMPANY [US/US]; 200 North Sepulveda Boulevard, El Segundo, CA 90245 (US).</p> <p>(72) Inventor: BARTELT, John, L. ; 1504 Folkstone Terrace, Westlake Village, CA 91361 (US).</p> <p>(74) Agents: COLLINS, David, W. et al.; Hughes Aircraft Company, P.O. Box 1042, Bldg. C-2, MS A-126, El Segundo, CA 90245 (US).</p>	<p>(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent).</p> <p>Published <i>With international search report.</i></p>
<p>(21) International Application Number: PCT/US84/01542</p> <p>(22) International Filing Date: 26 September 1984 (26.09.84)</p> <p>(31) Priority Application Number: 590,135</p> <p>(32) Priority Date: 16 March 1984 (16.03.84)</p> <p>(33) Priority Country: US</p> <p>(71) Applicant: HUGHES AIRCRAFT COMPANY [US/US]; 200 North Sepulveda Boulevard, El Segundo, CA 90245 (US).</p> <p>(72) Inventor: BARTELT, John, L. ; 1504 Folkstone Terrace, Westlake Village, CA 91361 (US).</p> <p>(74) Agents: COLLINS, David, W. et al.; Hughes Aircraft Company, P.O. Box 1042, Bldg. C-2, MS A-126, El Segundo, CA 90245 (US).</p>	<p>(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent).</p> <p>Published <i>With international search report.</i></p>			
<p>(54) Title: DISSIMILAR SUPERIMPOSED GRATING PRECISION ALIGNMENT AND GAP MEASUREMENT SYSTEMS</p>				
<p>(57) Abstract</p> <p>A substrate (10) having a diffraction grating (20) of a first periodicity formed thereon, a mask (22) having a diffraction grating of a second periodicity formed thereon, the mask and substrate being positioned such that the respective mask and substrate gratings are generally parallel opposing one another on the mask and substrate, means (42) for providing collimated coherent light (24) directed so as to impinge on the mask and substrate gratings, and means for separately collecting (46, 48, 50, 52), recombining (54, 56) and detecting (58, 60) the intensity of at least a first given order of diffracted light beams as respectively diffracted by the mask and substrate gratings.</p>				
<p>BEST AVAILABLE COPY</p>				

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GA	Gabon	MR	Mauritania
AU	Australia	GB	United Kingdom	MW	Malawi
BB	Barbados	HU	Hungary	NL	Netherlands
BE	Belgium	IT	Italy	NO	Norway
BG	Bulgaria	JP	Japan	RO	Romania
BR	Brazil	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	LI	Liechtenstein	SN	Senegal
CH	Switzerland	LK	Sri Lanka	SU	Soviet Union
CM	Cameroon	LU	Luxembourg	TD	Chad
DE	Germany, Federal Republic of	MC	Monaco	TG	Togo
DK	Denmark	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali		
FR	France				

-1-

DISSIMILAR SUPERIMPOSED GRATING PRECISION
ALIGNMENT AND GAP MEASUREMENT SYSTEMS

1 The Government has rights in this invention
pursuant to Contract No. N66001-82-C-0124 awarded by
the Department of the Navy.

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

 The present invention relates generally to a
precision overlay alignment system and, particularly,
10 to proximity and projection lithography systems wherein
ions, electrons or photons are utilized to transfer a
high resolution pattern from a mask to a substrate.

2. Description of the Prior Art

15 There is a continuing desire to further reduce the
minimum feature size of integrated circuits. This
imposes a requirement of repeatably obtaining an exceed-
ingly accurate degree of alignment between a mask and a
substrate for each sequential lithographic step in the
20 fabrication of an integrated circuit. For obtaining
integrated circuits having feature sizes of below 1.0
 μm , an interferomic technique appears to possess
the greatest likelihood of successful implementation.



- 1 D. C. Flanders et al., A New Interferomic Alignment
Technique, Applied Physics Letters, Vol. 31, No. 7,
1 October 1977, pp. 426-428, describes the basic inter-
feromic technique. Diffraction gratings of identical
5 period are provided on the facing surfaces of a mask
and substrate. The gratings are generally oriented
with respect to one another such that they are parallel.
A beam of laser light is directed normal to the diffrac-
tion grating planes with the result that diffracted
10 light is returned at discrete angles from the incident
laser beam, as may be determined by the equation:

$$n\lambda = d(\sin\phi_n - \sin\phi_i),$$

- 15 where n is the diffraction group number, λ is the
incident beam wavelength, d is the grating period and
 ϕ_n and ϕ_i are the angles that the diffracted and
incident beams make with respect to the normal of the
diffraction grating planes. Only those beams suffering
20 the smallest unit of an angular diffraction, those
that have suffered a net first order diffraction, are
utilized in the Flanders et al. technique. Further,
the Flanders et al. technique utilizes the fact that
the diffracted beams occur to either side of the incident
25 laser beam. Thus, the first order diffraction group
includes both plus ($n = +1$) and minus ($n = -1$) order
beams. The plus first order diffraction group is
composed of those beams that only suffer a plus first
order diffraction from the mask grating (indicated as
30 (1,0,0) in summary notation), or a sequential combination
of diffractions such as a zeroth order diffraction
from the mask grating, a plus first order diffraction
from the substrate grating, and a zeroth order diffraction
returning through the mask grating (0,1,0). The plus
35 first order diffraction group may also include such

1 beams that have sequentially suffered a zeroth order
diffraction through the mask grating, a minus first
order diffraction from the substrate grating, and a
plus second order diffraction through the mask grating
5 (0,-1,2). The result is an effective or net plus
first order diffraction. Due to the symmetry of the
gratings, a generally symmetrical set of beams are
diffracted by the mask and wafer gratings so as to
form both plus and minus first order diffraction groups.

10 The Flanders et al. technique measures the relative
difference in the plus and minus first order diffraction
group intensities to obtain an indication of the alignment
of the mask and substrate gratings. For an in-plane
displacement of the mask with respect to the substrate
15 less than the period of the gratings, there is a corres-
ponding variation in the relative intensities of the
plus and minus first order diffraction groups due to
the mutual interference between beams within each
group. Ideally, there is a zero intensity difference
20 between the plus and minus first order diffraction
groups only when the mask and substrate diffraction
grating lines are aligned. With the detection of
sufficiently small intensity differences Flanders et al.
concludes that alignment errors as small as 200Å can be
25 detected.

There are, however, a number of inherent problems
with the Flanders et al. technique. Of principal
significance is that the Flanders et al. technique is
highly sensitive to the specific spacing between the
30 mask and substrate. In practical applications, this
gap distance may vary due to bowing of the mask or
wafer, or both, the tolerance errors in the machinery
positioning the mask and substrate (particularly in
such systems where there is a substrate step and repeat
35 exposure sequence), and such transient perturbations



1 as due to thermal, acoustic, and mechanical vibrations.
These sources of gap distance variations further compound
the simple fact that a gap exists at all. This inter-
feromic technique relies on the interference between
5 the respective first order diffracted group beams
diffracted from the mask grating with those from the
substrate grating. Since there is a spacing between
the mask and substrate gratings, there is an inherent
difference in the path length traversed by the respective
10 mask and substrate grating diffracted beams. This
introduces an effective phase retardation in those
beams diffracted by the substrate grating. Thus, the
interference that naturally occurs between the mask
and substrate diffracted beams produces an equal intensity
15 change but of opposite effective polarity in the respec-
tive plus and minus group beams. Consequently, when
the mask and substrate gratings are in fact aligned,
there will be an inherent difference in the intensities
of the plus and minus first order diffraction group
20 beams due to the presence of the gap.

While a constant difference in intensity might be
appropriately dealt with, assuming the gap distance can
be accurately and independently quantitized, the various
causes of variations in the mask to substrate spacing
25 are essentially random transients not subject to practical
quantitization. Further, the variations in spacing
are typically an appreciable fraction of the otherwise
nominal gap distance. Consequently, there is no practical
way to discriminate between mask and substrate grating
30 alignment errors and the undesirable but nonetheless
present variations in the mask to substrate spacing.

Another practical problem with the Flanders et
al. technique is that it requires the diffraction
efficiency of both the mask and substrate gratings to
35 remain essentially constant and equal throughout the



1 processing of the substrate. The efficiency of the
mask grating may change due to the simple fact that
different masks are utilized for the different sequential
lithographic processing steps. However, the variations
5 in mask grating efficiency alone are tolerable. In
contrast, the effective diffraction efficiency of the
substrate grating is reduced by the simple fact that
the substrate grating diffracted beams must pass twice
through the mask grating. Further the substrate grating
10 is utilized throughout the processing of the substrate
and, therefore, is effectively exposed to the effects
of all of the processing steps. Thus, the substrate
grating efficiency degrades as the processing proceeds.
Degradation of substrate grating efficiency results in
15 a loss of its diffracted beam intensity and, thereby
reduces the interference modulation of the plus and
minus group beams. Consequently, for a given detector
sensitivity, loss of grating efficiency directly increases
the minimum limit of alignment error that can be detected.

20

SUMMARY OF THE INVENTION

The general purpose of the present invention is
to provide a highly accurate lithography alignment
system of practical utility.

25 This is accomplished by the present invention by
providing a mask and substrate alignment system comprising
a substrate having a diffraction grating of a first
periodicity formed thereon, a mask having a diffraction
grating of a second periodicity formed thereon, the
30 mask and substrate being positioned such that the
respective mask and substrate gratings are generally
parallel opposing one another on the mask and substrate,
means for providing collimated coherent light directed
so as to impinge on the mask and substrate gratings,
35 and means for separately collecting, recombining, and



1 detecting the intensity of at least a first given order
of diffracted light beams as respectively diffracted
by the mask and substrate gratings. An indication of
alignment between the mask and substrate gratings is
5 obtained by comparing the relative intensity of the
beams effectively diffracted only by the mask with
those only effectively diffracted by the substrate
with regard to their respective maximum obtainable
intensities for their given diffracted beam orders.

10 Thus, the present invention retains the elemental
simplicity of design and the capability for precision
alignment present in the basic interferomeric technique.

Another advantage of the present invention is
that it is insensitive to the presence of a gap between
15 the mask and substrate grating in positioning the
substrate with respect to the mask and, further, any
transient variations in the gap distance within reasonable
limits.

A further advantage of the present invention is
20 that it is substantially insensitive to an initial
difference and subsequent variations in the diffraction
efficiency of the mask and substrate gratings.

Yet another advantage of the present invention is
that it permits the direct measurement of the gap
25 spacing between the mask and substrate during the
positioning and subsequent maintenance of the substrate
with respect to the mask.

A still further advantage of the present invention
is that it is adaptable to a wide variety of proximity
30 and projection lithography systems.

1 BRIEF DESCRIPTION OF THE DRAWINGS

 These and other attendant advantages of the
present invention will become apparent and readily
appreciated as the same becomes better understood by
5 reference to the following detailed description when
considered in connection with the accompanying drawings,
in which like reference numerals designate like parts
throughout the figures and wherein:

 FIG. 1a is a perspective view of a portion of
10 a diffraction grating as used in the present invention;

 FIG. 1b shows the coordinate system to be
used in describing the orientation of the diffraction
gratings utilized in the present invention;

 FIG. 2 is a schematic representation of the
15 dissimilar superimposed diffraction gratings and the
diffraction of light therefrom;

 FIG. 3 is a diagrammatic view of a first
embodiment of an apparatus employing the present
invention; and

20 FIG. 4 is a diagrammatic view of an optimized
optical path embodiment of an apparatus employing the
present invention.

DETAILED DESCRIPTION OF THE INVENTION

25 The present invention was developed for use in a
proximity type high resolution masked ion beam lithography
(MIBL) system. Typically, such a system includes a
collimated ion beam source, a relatively immobile
ion-channeling replication mask, and an x-y translation
30 stage including a mount for holding a substrate. In
accordance with the present invention, the substrate
is preprocessed to form gratings thereon substantially
as represented in FIG. 1a. The gratings can be formed,
using ordinary photolithographic techniques as a simple
35 resist pattern on the surface of the substrate or



1 etched directly into either the surface of the substrate
or a layer formed thereon. Preferably, the diffraction
grating is etched permanently into the substrate so as
to provide a pattern having a constant period d of
5 approximately $2\text{ }\mu\text{m}$ and a line width of $d/2$. The
height h of the diffraction grating lines is generally
selected to optimize its reflective diffraction efficiency
with respect to a given diffraction order, preferably
the first, and, as such, is selected depending on the
10 wavelength of the incident alignment light beam, the index
of refraction of the substrate and any layers thereon.
Preferably, the source of incident alignment light is
a low power laser producing a well collimated beam of
coherent light. While a variety of lasers may be
15 used, such as HeNe and Ar^+ , to provide an alignment
light beam at any one of a wide range of frequencies,
a HeNe laser emitting light having a wavelength of
approximately 632.8 nanometer is preferred. For a
diffraction grating etched into a silicon substrate,
20 and generally meeting the above criteria, this incident
beam wavelength corresponds to a diffraction grating
line height h of approximately 3000Å.

The mask grating is formed as a relief pattern
provided as part of the ion-channeling mask. Dissimilar
25 grating periods are chosen for the mask and substrate
gratings in accordance with the present invention.
The period of the mask grating is preferably chosen to
be larger than that of the substrate to obtain the
greater transmission efficiency inherent with relatively
30 larger grating periods and, thereby, optimize the
amount of zeroth order diffraction light passing through
the mask grating. The basis for the selection of the
two dissimilar grating periods will become apparent
from the discussion below. Preferably, the mask grating
35 period d is chosen as approximately equal to $3\text{ }\mu\text{m}$



- 1 with a line width of $d/2$ or $1.5 \mu\text{m}$. The height h and,
in particular, the cross sectional shape of the mask
grating lines are selected to balance the diffraction
efficiency between the zeroth order transmission of
5 the incident beam and the reflective diffraction of
first order diffraction beams.

- The mask and substrate are overlaid in close
proximity to one another so as to superimpose the
dissimilar gratings of the mask and substrate.
- 10 Preferably, pairs of gratings are provided along each
edge of the mask and oriented within the plane of the
mask at 90° with respect to one another. Substrate
gratings are correspondingly located and oriented.
This allows orientation of the mask and substrate in
15 both the x and y direction of the coordinate system
indicated in FIG. 1b. As will be explained below,
this further allows for the proper rotational or theta
alignment of the mask and substrate. As will also be
explained in greater detail below, alignment of the mask
20 and substrate in the z direction is essentially
noncritical for x - y alignment. The present invention,
however, provides for precision z distance measurement
and alignment that is substantially insensitive to the x - y
relative location of the gratings.

- 25 Referring now to FIG. 2, a schematic representation
of the diffraction of an incident beam of light 24 from
dissimilar superimposed gratings 20, 22 is shown. The
direction of the beams generated by the diffraction of
the incident beam 24 is given by:

30

$$n\lambda = d(\sin\phi_n - \sin\phi_i), \quad (1)$$

- where n is the diffraction group number, λ is the
incident beam 24 wavelength, d is the grating period and
35 ϕ_n and ϕ_i are the angles that the diffracted and
incident beams make with respect to the normal of the



1 diffraction grating planes. Considering for purposes
of the present invention only the first order diffraction
group and selecting $\phi_1 = 0$, the diffracted beam
angles ϕ_1, ϕ_2 from the plane of the incident
5 beam 24 normal to the mask and substrate gratings and
parallel to the length of the diffraction grating
lines is given by:

$$\phi_n = \sin^{-1}(\lambda/d). \quad (2)$$

10 The use of dissimilar superimposed diffraction gratings
thus results in the spatial separation of the respective
plus and minus first order diffraction beams as respec-
tively diffracted from the substrate grating 20 and
the mask grating 22. For the preferred incident beam
15 24 wavelength and the preferred grating periods as
noted above, ϕ_1 is equal to approximately 12.18°
and ϕ_2 equals approximately 18.44° . The selection
of the particular grating periods is based on the
practical considerations of providing sufficient spatial
20 separation between the respective plus and minus first
order diffracted beams 26, 30, and 28, 32 so as to
permit their subsequent manipulation in accordance
with the present invention. The selection of the
grating periods is also based on the practical
25 consideration that the capture range of the alignment
technique of the present invention is approximately
one-half of the smaller of the two grating periods.
The relative phase of the plus and minus order diffracted
beams directed at diffraction angles given by Equation 2
30 for a given order will vary as the position of the
corresponding diffraction grating is shifted laterally.
The plus and minus order beams are coherently recombined
with the result that the position information is converted
to an intensity variable by mutual coherent interference.
35 The magnitude of the beam intensity and the position



1 of a grating can be related by deriving the time averaged
Poynting vector magnitude for the recombined diffracted
beams. In the context of the present invention for the
mask grating alone (or, in the presence of the substrate
5 grating, where the reflected zeroth order substrate
grating reflectively diffracted beam is otherwise
blocked) or the substrate grating either in the presence
or absence of the mask grating, the time average Poynting
vector magnitude is:

10
$$|\vec{S}| = \cos^2\left(\frac{2\pi\epsilon}{d}\right) \quad (3)$$

where ϵ is the lateral displacement and d is the grating
period of the corresponding displaced grating. The
cosine squared function evaluates to two complete cycles
15 of intensity as ϵ goes from zero to d . Consequently,
a nonambiguous alignment position can only be obtained
if the superimposed dissimilar gratings are initially
aligned with respect to one another within one-half of
the period of the smaller of the two gratings.

20 In order to increase the capture range, larger
grating periods can be utilized. In the case of grating
periods of 10 and 11 μm for the substrate and mask
gratings, respectively, a capture range of approximately
5 μm can be obtained. However, the spatial separation
25 of the first order diffracted beams as diffracted from
the mask and the substrate gratings, respectively, are
substantially reduced. The first order diffraction
angle for a diffraction grating of 10 μm is approximately
3.63° and, for a grating of a period of 11 μm , the
30 diffraction angle is approximately 3.29°, based on an
incident beam wavelength of 632.8 nanometers.



1 Another consideration in choosing the periods of
the dissimilar diffraction gratings is that the larger
diffraction grating periods inherently are associated
with a lower diffraction efficiency. This results in
5 a significant reduction of the available diffracted
beam intensity. Preferably, for a grating pair, the
smaller grating period is np and the larger is $np+1$,
where n is an integer and p is a unit length on the
order of a micrometer.

10 In view of the foregoing, an optimal solution to
the choice of dissimilar diffraction grating periods is
to simply provide multiple pairs of superimposed
dissimilar gratings of, preferably, 2 and 3 μm periods
and 10 and 11 μm periods, respectively. This allows
15 the larger capture range of the larger grating period
pair to be utilized to place the mask and substrate in
sufficient alignment to be within the capture range of
the greater available precision of the smaller grating
period pair. Thus, the advantages of using both the
20 large and small dissimilar grating periods are obtained.

It is important to recognize from Equation 3 that
the intensity magnitude of a recombined beam is dependent
only on the lateral position of a single corresponding
grating and not at all dependent on the gap distance
25 between the mask and substrate gratings. Thus, for those
cases noted above in which Equation 3 applies, the
determination of alignment is independent of the presence
of a mask to substrate gap or any variation therein.

In the sole case where zeroth order mask transmitted
30 beam is returned back through the mask as a zeroth
order substrate grating diffracted beam, there will be
a detectable variation in the intensity of the mask
diffracted and subsequently recombined beam as measured
at the mask position detector. The zeroth order trans-
35 mitted beam may be returned by a reflective zeroth order

1 diffraction from the substrate grating or, in the
 absence of any substrate grating, simply reflected by a
 specular area of the substrate. This reflected zeroth
 order beam will be diffracted, at least in part, by the
 5 mask grating, thereby, producing plus and minus first
 order diffracted beams $(0,0,\pm 1)$. These beams will
 mutually interfere with the corresponding singly
 diffracted first order beams $(\pm 1,0,0)$ diffracted
 by the mask. Consequently, the recombined mask first
 10 order diffracted beam intensity will have a Poynting
 vector magnitude given by:

$$|\vec{S}| = 2(1 + 2\cos 2\phi), \quad (4)$$

where

$$15 \quad \phi = g\left(\frac{2\pi}{\lambda}\right) \left[1 - \sqrt{1 - \left(\frac{\lambda}{d}\right)^2}\right], \quad (5)$$

and where g is the gap spacing, λ is the wavelength of
 the incident beam, and d is the period of the mask
 diffraction grating. Thus, assuming the position of
 20 the mask grating is first established, the present
 invention permits the accurate measurement of the mask
 to substrate gap spacing g based on the measured intensity
 of the recombined mask diffracted beam. Of particular
 advantage is that the gap measurement is essentially
 25 independent of the specific lateral position of the
 substrate grating.

Referring now to FIG. 3, a complete optical system
 embodying the present invention is shown schematically.
 The alignment apparatus 40 includes a laser source 42
 30 and an incident beam mirror 44 arranged to direct an
 incident beam 62 toward the substrate and mask gratings
 20, 22. The substrate and mask gratings 20, 22, shown
 not to scale, diffract the first order diffracted
 beams toward corresponding collection mirrors 46, 48,

1 50, 52. The respective collection mirror pairs 46, 48
and 50, 52 collect the respective plus and minus first
order diffracted beam pairs 64, 66 and 68, 70 and
redirect them to the beam splitters/recombiners 54,
5 56, respectively. The separate first order diffracted
beams are recombined by mutual coherent interference
at their respective beam splitters 54, 56 and pass on
to the detectors 58, 60. These detectors are preferably
semiconductor opto-detectors selected as being sensitive
10 to optical radiation of the same wavelength as the
light emitted by the laser light source 42. Since the
grating periods of the substrate and mask gratings 20,
22 are dissimilar and by the unique placement of the
collection mirrors 46, 48, 50, 52, only the first
15 order diffracted beams that have further suffered only
a single non-zero order diffraction are collected.
All higher order diffracted beams as well as all first
order diffraction group beams that have been multiply
diffracted will emerge from the substrate and mask
20 gratings at sufficiently different spatially distributed
diffraction angles to permit the selection of only the
first order singly diffracted beams $64(-1,0,0)$, $66(1,0,0)$
and $68(0,-1,0)$, $70(0,1,0)$. The placement of the collec-
tion mirrors 46, 48, 50, 52 and the beam splitters 54,
25 56, is further selected such that there is a common
path length for both the plus and minus first order
singly diffracted beams that are respectively diffracted
from the mask and substrate gratings 20, 22. Naturally,
the coherence length of the laser light source 42 must
30 be greater than the optical path length from the laser
42 to either detector 58, 60.

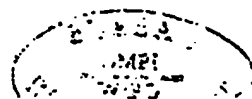
1 An alternate embodiment of the present invention
is shown in FIG. 4. The alignment system 80 again
includes the laser source 42 and incident beam mirror
44 for directing an incident laser beam 62 so as to
5 impinge on the dissimilar superimposed substrate and
mask gratings 20, 22. A single pair of collection
mirrors 82, 84 are positioned to collect the respective
minus and plus first order singly diffracted beams
64(-1,0,0), 68(0,-1,0) and 66(1,0,0), 70(0,1,0) and
10 redirect them along separate optical paths to a common
beam splitter/recombiner 86. The respective first
order singly diffracted beams are effectively recombined
by mutual coherent interference at the beam splitter
86 and directed to respective detectors 90, 92. Similar
15 to the previous alignment system 40, the collection
mirrors 82, 84 are positioned so as to collect only
the first order singly diffracted light from the mask
and wafer gratings 22, 20. Path length compensation
is accomplished by the provision of a standard Soleil-
20 Babinet compensator placed in the path of the plus
first order singly diffracted beams 66, 70 from the
mask and substrate gratings 22, 20. Thus, path length
compensation is obtained relatively independent of the
placement of the collection mirrors 82, 84. Consequently,
25 the placement of the collection mirrors 82, 84 may be
optimized so as to collect only the first order singly
diffracted group 64, 66, 68, 70.

 In a practical application, a number of alignment
systems 40 or 80 are utilized as subsystems within a
30 lithography system, such as MIBL. Each alignment
subsystem is utilized to derive x or y alignment
information from a corresponding superimposed dissimilar
diffraction grating pair. Preferably, at least four



1 such subsystems are utilized with four corresponding
dissimilar superimposed grating pairs spaced equally
about the periphery of a typically square area, the
diagonally disposed grating pairs sharing a common
5 grating line orientation that is rotated in-plane 90°
from that of the other two grating pairs.

In operation, an initial alignment between a
mask and a substrate is obtained by first moving the
mask in a given x direction and observing the intensity
10 phase change at the corresponding detectors. At this
point, the return of any zeroth order mask grating
transmitted beam must be prevented as may be accomplished
by simply not providing the substrate in the vicinity
of the mask. The mask grating can be moved by physically
15 translating the position of the mask. Preferably,
however, the effective position of the mask can be
modified by adjusting the relative path length of the
plus and minus first order singly diffracted beams.
This may be accomplished through the use of the compen-
20 sator 88 of FIG. 4. Positioning the compensator 88 so
as to modify the corresponding plus first order singly
diffracted beams 66, 70 from the mask and substrate,
respectively, prevents the introduction of a relative
path length difference error thereinbetween. Thus, as
25 the mask grating is laterally displaced, effectively
or otherwise, the recombined mask beam detector 92
will observe a sinusoidal variation in the intensity
of the recombined first order singly diffracted beam
incident thereon. Any phase point along the sinusoidal
30 variation in intensity can be selected as a null position
point. If necessary, the mask may be rotated as well
as shifted, effectively or otherwise, so that a common
null point is observed by the detector of both of the
x direction subsystems. A y direction mask null point
35 is similarly selected. The substrate is then moved



1 into the vicinity of the mask so as to superimpose the
gratings within the appropriate capture range. Null x
and y positions for the substrate x and y direction
gratings are then selected similarly. Although the
5 present invention permits the x and y phase point
nulls of the mask to be selected independently of one
another as well as either of the x and y phase point
nulls of the substrate, preferably all of the phase
point nulls are selected to be 90° past the maximum
10 intensity obtainable at their respective detectors
when moved within their capture ranges in a given x or
y direction. Subsequent alignments between the mask
and substrate are accomplished by placing the mask and
substrate in sufficiently close alignment, in both the
15 x and y directions, so as to again be within the capture
ranges of the various dissimilar superimposed diffraction
gratings. The substrate is then again translated in
the x and y directions until the intensities measured
at the various detectors correspond substantially to
20 the intensity phase point nulls selected during the
initial alignment.

Consistent with the foregoing, during the
positioning for and subsequent maintenance of the
aligned position of the substrate, the mask to substrate
25 gap spacing can be measured and continually monitored
by observing the intensity of the mask signal at the
recombined mask beam detector 92 in view of Equations
4 and 5. Naturally, the position of the substrate can
be modified as necessary to obtain the desired gap
30 spacing and plane parallelism between the mask and
substrate.

The present invention thus provides a method of
obtaining interferomic precision alignment between
dissimilar period superimposed diffraction gratings
35 that can be implemented in a simple and highly reliable



1 optical system. As such, the present invention permits
the precision alignment of the dissimilar superimposed
diffraction gratings to be obtained and maintained
substantially independent of variations in the spacing
5 between the relative diffraction efficiency of the
dissimilar period gratings. Further, the present
invention permits the interferomic precision measurement
of and, thereby, control of the mask to substrate gap
spacing.

10 It should be understood, of course, that the
foregoing is a description of the preferred embodiments
of the present invention and that many modifications
and variations are possible in light of the above
teachings. These modifications and variations include,
15 but are not limited to, utilizing laser light sources
of different selected wavelengths, folding the optical
path of the alignment system so as to obtain nonsymme-
trical diffraction from the mask and substrate gratings,
positioning the optics to collect, recombine, and detect
20 diffraction order beams of one given order to obtain a
mask position signal and of another given order to
obtain a substrate position signal, utilizing different
materials to form the mask, pairing mask gratings with
plane substrate surfaces to obtain gap measurement
25 sites alone or separate from dissimilar grating alignment
sites, and utilizing the present invention in other
proximity and projection pattern replicating lithography
systems. It is therefore to be understood that, within
the scope of the appended claims, the invention may be
30 practiced otherwise than is specifically described
above.

CLAIMSWhat is Claimed is:

- 1 1. A proximity interferomic alignment system
comprising:
- a) a substrate having a diffraction grating
of a first periodicity formed thereon;
- 5 b) a mask having a diffraction grating of a
second periodicity formed thereon, said mask and
substrate being provided in close proximity to one
another so as to substantially superimpose said mask
and substrate gratings;
- 10 c) means for providing a collimated coherent
lightbeam directed so as to impinge on said mask and
substrate gratings; and
- d) means for separately collecting, recom-
bining, and detecting the intensity of a first given
15 order of singly diffracted lightbeams as diffracted by
said mask grating and of a second given order of singly
diffracted lightbeams as diffracted by said substrate
grating.
- 1 2. The interferomic alignment system of Claim 1
further comprising:
- a) means for adjusting the in-plane position
of said mask with respect to said collecting, recombining
5 and detecting means; and
- b) means for adjusting the in-plane position
of said substrate with respect to said collecting,
recombining and detecting means.
- 1 3. The interferomic alignment system of Claim 2
further characterized in that said mask and substrate
gratings are provided on respective facing surfaces of
said mask and said substrate.



1 4. The interferomic alignment system of Claim 1 further characterized in that the periods of said masks and substrate gratings are between approximately one and fifteen microns.

1 5. The interferomic alignment system of Claim 4 further characterized in that the periods of said mask and substrate gratings differ by approximately one micron.

1 6. The interferomic alignment system of Claim 1 further characterized in that said first given order and said second given order of diffracted light both correspond to first order singly diffracted light from said mask and said substrate gratings, respectively.

1 7. An interferomic alignment system for the precision alignment of a first element with a second element comprising:

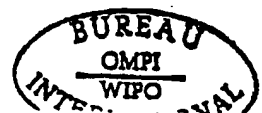
5 a) a first diffraction grating of a first periodicity associated with said first element;

 b) a second diffraction grating of a second periodicity associated with said second element;

10 c) means for positioning said first and second elements such that said first and second grating are superimposed with respect to one another;

 d) means for providing collimated coherent light directed so as to impinge on said first and second gratings;

15 e) collection optics for selecting and redirecting the plus and minus diffraction beam pairs of a first given diffraction order from said first grating and a second given diffraction order from said second grating;



20 f) recombination optics for receiving the
redirected beam pairs from said collection optics and
recombining the respective beam pairs by mutual coherent
interference to obtain a first element recombined beam
and a second element recombined beam, respectively; and

25 g) first and second detection means for
separately detecting the intensity of said first and
second element recombined beams, respectively.

1 8. The system of Claim 7 wherein said first and
second diffraction gratings are provided in close
proximity to one another as appropriate for use in a
proximity lithography system.

1 9. The system of Claim 7 further comprising
projection optics interposed between said first and
second elements so as to permit the demagnified projection
of a pattern from said first element to be imaged on
said second element as appropriate in a projection
5 lithography system.

1 10. The system of Claims 8 or 9 wherein the period
of said second grating is essentially infinite with
respect to that of said first grating.

1 11. An interferomic gap measurement system for
the precision measurement of the distance between a first
element and a second element comprising:

5 a) a diffraction grating of a given periodicity
associated with said first element;

b) a reflective surface area associated with
said second element;

10 c) means for positioning said first and
second elements such that said grating is superimposed
over and is substantially-plane parallel with said
reflective surface area;



1 / 2

Fig. 1a.

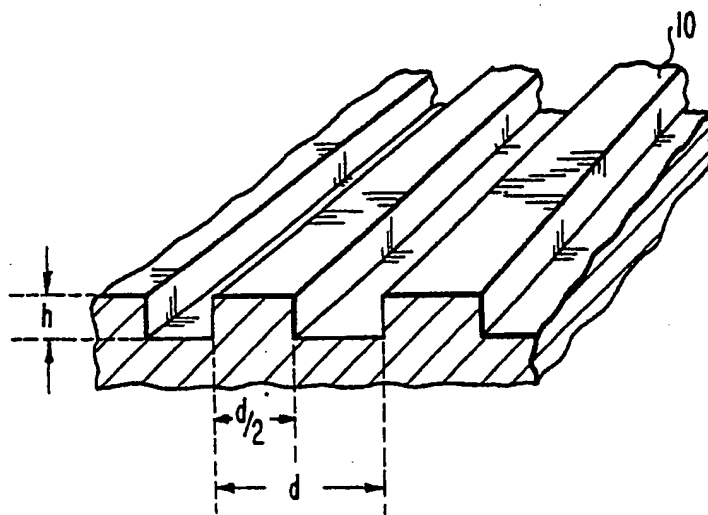


Fig. 1b.

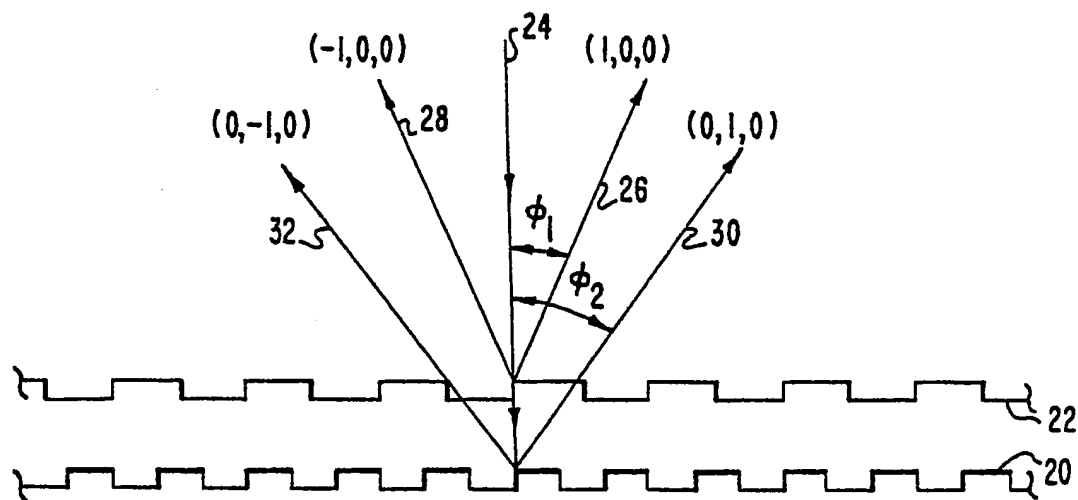
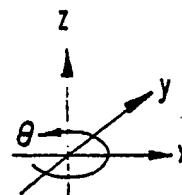


Fig. 2.

2/2

Fig. 3.

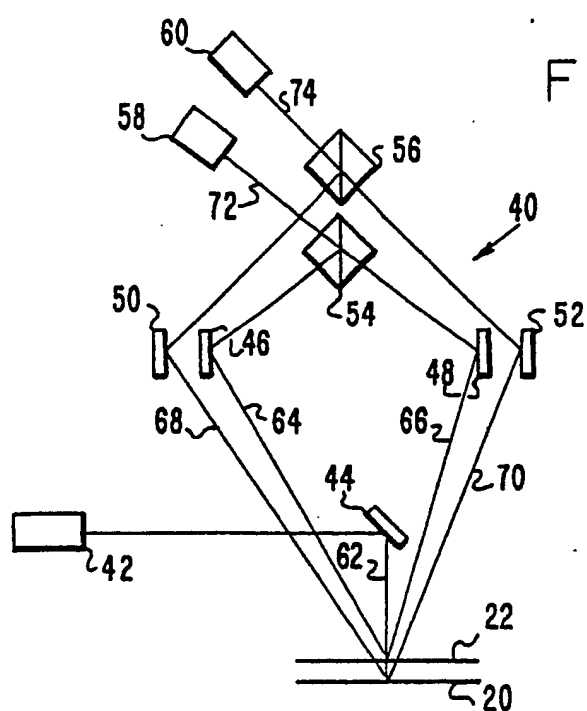
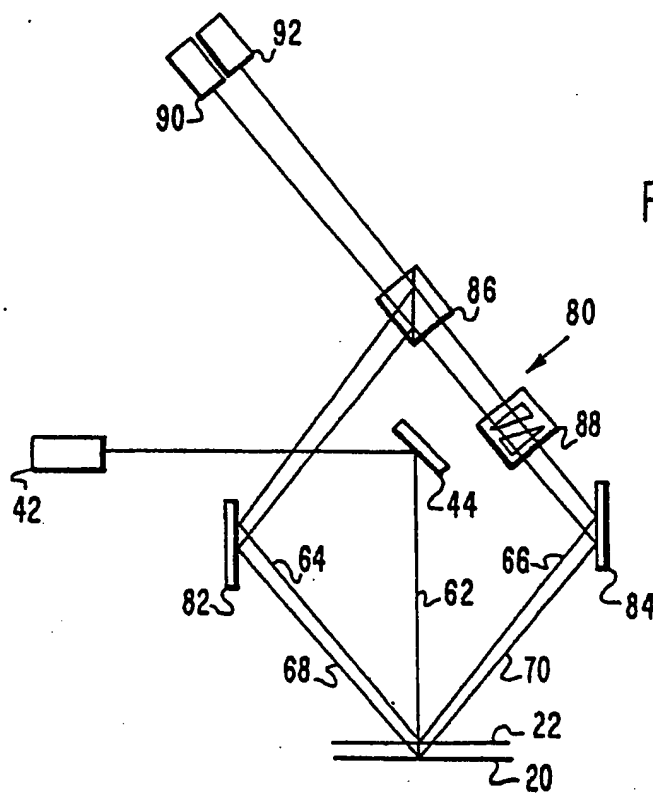
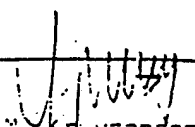


Fig. 4.



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 84/01542

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ¹	
According to International Patent Classification (IPC) or to both National Classification and IPC	
IPC ⁴ : G 03 B 41/00; G 01 B 11/27	
II. FIELDS SEARCHED	
Minimum Documentation Searched ⁴	
Classification System :	Classification Symbols
IPC ⁴	G 03 B 41/00; G 05 D 3/00; G 01 B 11/27
Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched ⁵	
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴	
Category ⁶ :	Citation of Document, ¹⁴ with indication, where appropriate, of the relevant passages ¹⁷ Relevant to Claim No. ¹⁸
Y	Applied Physics Letters, vol. 31, no. 7, October 1977 (New York, US) D.C. Flanders et al.: "A new interferometric alignment technique", pages 426-428, 1,4,6,7,8,11 see page 427, left-hand column, lines 1-19; figure 3 (cited in the application)
Y	US, A, 4200395 (SMITH) 29 April 1980 see column 4, line 64 - column 5, line 1-3,7,8,11 3; column 6, line 56 - column 3, line 47; column 9, lines 5-10; claim 3
A	US, A, 4251160 (BOUWHUIS) 17 February 1981 see abstract; page 1 9
A	EP, A1, 0010998 (THOMSON CSF) 14 May 1980 see figure 1 10
A	IBM Technical Disclosure Bulletin, vol. 23, no. 7A, December 1980 (New York, US) D.C. Hofer: "Coarse and fine align- ment using out-of-phase pair of optical ./.
<p>[*] Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>	
IV. CERTIFICATION	
Date of the Actual Completion of the International Search ¹	Date of Mailing of this International Search Report ²
13th December 1984	19 FEB. 1985
International Searching Authority ¹	Signature of Authorized Officer ¹⁹
EUROPEAN PATENT OFFICE	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
------------	--	------------------------------------

	gratings", pages 2996-2998, see the entire document -----	1
--	--	---

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☒ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.